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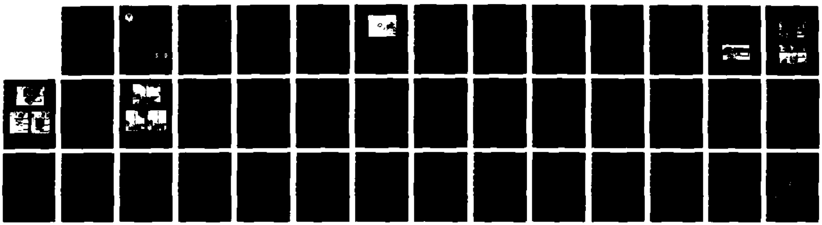

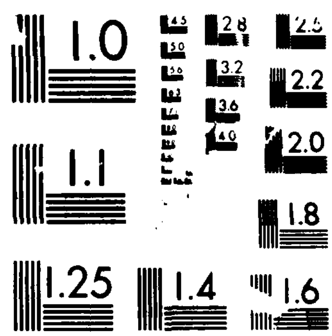

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US ARMY
MATERIEL COMMAND

INSTRUMENTATION DEVELOPMENT

FINAL REPORT

ON

AUTOMATED PEAK CHAMBER PRESSURE MEASUREMENTS SYSTEM (APCPMS)

BY

BRUCE BUZZO

JULY 1987

TECHNICAL TEST SUPPORT DIVISION
MATERIEL TEST DIRECTORATE

U.S. ARMY YUMA PROVING GROUND
YUMA, ARIZONA

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Automated Peak Chamber Pressure Measurement System (APCPMS) was designed, built, and programmed to measure the height of the crushed copper spheres which is a function of the internal peak chamber pressure generated during weapon firing programs. A trial test was conducted with a sample size over a predetermined pressure range window. Results were compared with previously used measurement methods. By eliminating operator-error factors, the APCPMS demonstrated that it was a more reliable and accurate means of obtaining peak chamber pressure measurement data. It was recommended that another computer system be used to improve visibility of display, and a more extensive test be conducted over a wider pressure range.

The APCPMS consists of the following components: a gaging fixture (LVDT), a microcomputer based controller, and a printer.

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TABLE OF CONTENTS

FOREWORD

This project was conducted by the engineering Support Branch, Technical Test Support Division, Materiel Test Directorate, U.S. Army Yuma Proving Ground. The assistance of the Metalworking Branch is gratefully acknowledged.

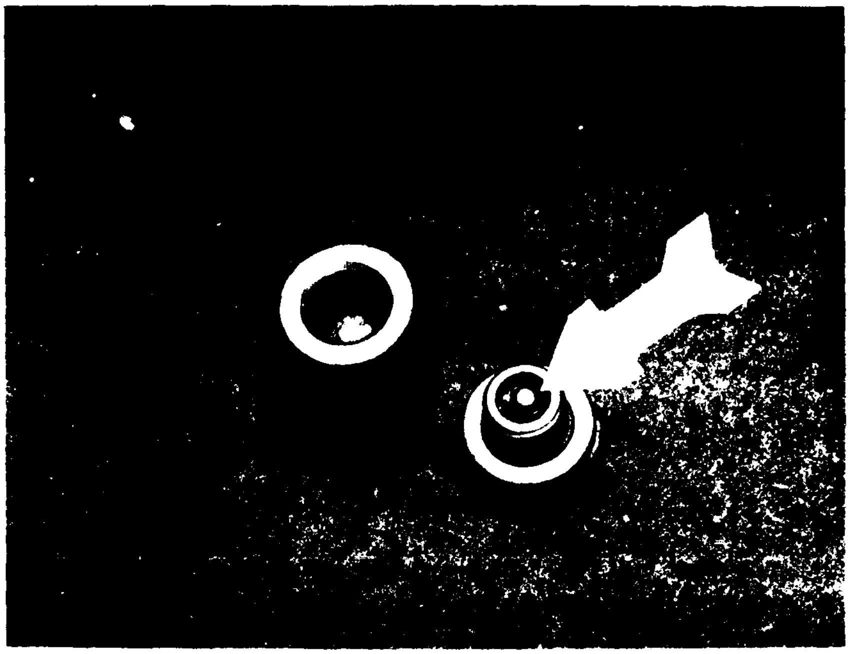


FIGURE 1. Peak Chamber Pressure Gage disassembled showing copper crusher sphere

AUTOMATED PEAK CHAMBER PRESSURE MEASUREMENT SYSTEM

SECTION 1. INTRODUCTION

1.1 BACKGROUND

Chamber pressures, or pressures which are produced in weapons by propellent gases during firing tests, are often measured with a mechanical crusher gage. The crusher gage is used to obtain peak firing chamber pressure. It consists of a cylinder, piston, anvil, and crushable element. See Figure 1.

There are several types of gages available for testing support, both external and internal. The particular gage type used during a firing test depends on such variables as the type and caliber of weapon, propellent charge used, temperature differentials, and the anticipated chamber pressure measurements.

Traditionally, the crushable element used in conjunction with the crusher gage can be of different size, shape, and material such as copper, aluminum, or ingot iron. In fact, prior to 1962, the majority of pressure data on U.S. Army artillery was obtained by cylinder crusher gages. After 1962, however, these cylinders were deemed obsolete by the U.S. Army Test and Evaluation Command (TECOM), and were replaced with a copper sphere. This replacement occurred for several reasons. First of all, unlike the cylinder which offers a constant area of resistance to force applied at its ends, the resistance area of the copper sphere increases with the force applied. This use of the sphere offers the advantage of relatively large compressions at low pressures, and relatively small compressions at high pressures. In addition, the spheres are cheaper and easier to produce than cylinders, and the spheres can be used in all gage types, while the cylinders cannot. Today the crusher gage using a copper sphere is one of the standard instruments employed by TECOM test agencies to measure the pressure of propellent gases in weapons.

Normally two gages are used per round when a firing test is conducted to measure chamber pressures with a copper sphere. One gage is placed at the 10 o'clock position and the other at the 2 o'clock position. A copper sphere is placed inside each gage. Then the gage is placed in the breach of the weapon. The orifice of the gage points toward the muzzle of the weapon. Chamber pressure entering through the orifice exerts pressure on the piston permanently deforming the sphere between the piston and anvil. Peak chamber pressure measurement for gages conditioned at 70°F as a function of the final height across the flats of the crushed sphere is obtained for a particular lot number and gage type by entering a tarage table which relates the sphere's compression to an equivalent ballistic pressure.

The tarage tables and polynomial equations are derived at Aberdeen Proving Ground for each lot of copper spheres by subjecting samples of the balls to a representative range of deforming loads using dynamic pressure

generators that simulate firing conditions. See Appendix A. Four calibrated tourmaline piezoelectric pressure transducers are used to monitor and record the pressure transients developed in the fluid chamber of the generators. The average load (average pressure of the tourmaline transducers times the crusher gage piston area) is plotted against the final height across the flats of the metal spheres to form a curve from which a tarage table is computed. When crusher gages are conditioned to other than 70°F, a temperature correction factor is applied to the final height across the flats of the metal sphere to obtain the final peak pressure. The temperature correction tables and equation(s) are derived by Aberdeen Proving Ground. See Appendix B.

While the crusher measurement gage has been a reliable means of deforming the sphere, obtaining reliable data using a 1-inch analog micrometer has been questionable. Errors have been found in:

a. The measurement instrument (a 1-inch Analog Micrometer).

b. The ability of the operators to obtain and repeat the same measurement pressure on the sphere.

c. Operators' ability to read measuring instrument correctly.

d. Transposition of numbers in the pressure gage records.

e. Obtaining the wrong pressure from the tarage table or using the incorrect table for a particular gage or lot number.

f. Obtaining the wrong temperature correction factor from the table or using the incorrect temperature correction tables.

g. Typing or interpreting the hand written pressure gage records for the final report.

In lieu of these inherent problems, a need existed to obtain peak chamber pressure and eliminate the human error, (elements as described above). In addition, there was a need for an historical record of the test data upon which to base a replacement schedule for the individual gages which tend to wear out. This data (i.e., tube, round number, final average height and pressure est.) needed to be derived and transmitted electronically to the final destination, the test report, without human error elements.

1.2 DESCRIPTION OF INSTRUMENTATION

The Automated Peak Chamber Pressure Measurement System was developed from standard commercially available components and also from in-house designed components. It consists of three main assemblies which are interconnected by flat cables. The three assemblies are the gaging fixture, a microcomputer based controller, and a printer.

The gaging fixture was designed and built in-house. An arbor mechanism holds a linear variable differential transformer (LVDT) with a spring loaded core. The core is displaced slightly by the copper as it is moved under the core plunger by the slide of a transport mechanism. The LVDT generates a signal proportional to the displacement of its core. A very sensitive LVDT was chosen so that the output ranges from -10 volts dc to +10 volts dc for a movement of only one-quarter inch (approximately 80 volts per inch). The commercially available LVDT has built-in signal conditioning for dc operation.

The gaging fixture also has light beam interrupters to detect when the slide is at the limits of its travel and a switch to indicate when the slide is in the gaging position. These features are intended to allow the computer to enforce a certain sequence of operation. The current version of the control program does not use these features.

The controller is connected to the gaging fixture by a 25 conductor flat cable similar to that used for the printer except that the male and female connectors are reversed to help prevent incorrect hookups. A regulated power supply in the controller box provides the +15 vdc and -15 vdc required by the LVDT. The controller also contains the STD-BUS card cage, power supplies, a 5-1/4 inch floppy disk drive, and a small portable computer with keyboard and display for use as a terminal.

The STD-BUS contains the CPU card, a disk drive controller card, a magnetic bubble memory card, a bubble memory controller card, an analog-to-digital (A/D) converter card, and a power interface card.

The CPU card is equipped with a Z-80 microprocessor, memory, and two RS-232C serial communication ports. The ports are used for communication with the terminal computer and the printer.

The disk controller card is connected to the quad density floppy disk drive. The drive is capable of storing over 622,000 characters of programs or data.

The magnetic bubble memory cards emulate a disk memory with over 256,000 characters capacity. Data and programs are stored as magnetic domains that remain even after power is turned off so the application programs can be run immediately after applying power.

The analog-to-digital converter card uses a high speed, 12-bit, successive approximation converter. The 12-bit converter measures an input of -5 volts to +5 volts in 4,096 steps to provide a resolution of approximately 0.0024 volts.

The controller is housed in a sturdy aluminum enclosure that was designed to provide adequate security and accessibility for the internal components.

The 80-column dot matrix impact printer is the last main assembly of the system.

The microcomputer consists of a CPU card, a disk drive controller and card, a bubble memory card, an A/D converter card, a power interface card, and a terminal.

1.3 OBJECTIVE

The objective of this instrumentation development project was to automate the copper crusher element measuring and reporting operation by developing the hardware, software, and operational procedure for a computerized measurement system that would be more reliable and also enhance data turn-around time.

1.4 SUMMARY OF RESULTS

A prototype Automated Peak Chamber Pressure Measurement System was designed, built, and programmed to perform the functions required. Tests were conducted including operation by the expected users of the system. Complaints were received about the visibility of the display and the lack of compatibility of the floppy disks with other personal computers.

Three separate tests were conducted which used the Automated Peak Chamber Pressure Measurement System (APCPMS) to determine the peak chamber pressures of eighteen copper spheres. The copper balls had previously been fired in the M11 Gage, two to a tube round, at either -35°F or 110°F. After firing, the compressed spheres were measured at both the Measurements and Material Analysis Section, and Calibration Laboratory. The Measurements and Material Analysis Section used a 1-inch, hand-held analog micrometer to measure the copper spheres, while the Calibration Laboratory used a 1-inch, hand-held digital micrometer. The spheres were then measured in three separate tests using the APCPMS. Before each run, the gage was recalibrated to ensure data reliability. Section 2 shows the results of the APCPMS tests in terms of the spheres' height, then compares this data with measurements made by the Measurements and Material Analysis Section and the Calibration Laboratory. Section 2 also compares the average pressure measurements of the spheres as derived by the Measurements and Material Analysis Section and the APCPMS.

1.5 ANALYSIS

It was found that the liquid crystal display (LCD) of the built-in terminal computer lacks adequate contrast and viewing angle for ease of use. The quad density disk drive requires higher quality and more expensive media than common personal computers. It may also be more susceptible to errors than less dense disks.

The trial test demonstrated that the APCPMS provided more accurate and reliable data than the present system used by Measurements and Material Analysis Section (using the Calibration Laboratory results as a standard, ref Table 1).

The test was conducted with a sample size over a predetermined pressure range window.

1.6 CONCLUSIONS

The Automated Peak Chamber Pressure Measurement System can effectively perform its function if shortcomings related to the display and disk drive are corrected.

By largely eliminating operator-error factors and instrument bias, the APCPMS provides a more reliable and accurate means of obtaining peak chamber pressure measurement data.

1.7 RECOMMENDATIONS

a. The system controller should be converted from the CP/M operating system to the MS-DOS operating system to provide improved compatibility with other computers in use locally.

b. The liquid crystal display along with the terminal computer should be replaced with a CRT and keyboard.

c. The application program should be revised to use the built-in sensors to enforce the proper loading, measuring, and ejection sequence.

d. The program should be revised to allow easier editing and to protect against accidental loss of programs and data.

e. The system should be subjected to an extensive test in comparison with established techniques to provide a statistical measure of any improvement in reliability and speed of operation.

f. The APCPMS technique should become the TECOM standard for accurately and reliably measuring peak chamber pressure.

g. TECOM should replace all manual methods of performing chamber pressure measurements.

SECTION 2. DETAILS OF TASK

2.1 CHRONOLOGY OF PROJECT

With the increasing number of weapon firing problems, the Test Engineering Division in 1978 suggested to Methodology and Instrumentation Division (MMI) a way in which to measure copper spheres to eliminate the inherent human errors. In 1985, the Instrumentation portion of MMI, now called the Engineering Support Branch, designed and had fabricated a fixture housing a linear variable differential transformer (LVDT) that was interfaced to a computer to measure the height of the copper spheres. In 1987, the software and operational procedure was written to obtain the necessary test data. This combination of hardware, software, and operational procedure was identified as the Automated Peak Chamber Pressure Measurement System (APCPMS).

2.2 DESCRIPTION OF APCPMS

The Automated Peak Chamber Pressure Measurement System hardware consists of a gaging fixture, a microcomputer, a power supply, and a printer. See Figure 2. The software consists of a basic language program (App F). An operational procedure for using the hardware and software is contained in this report.

Essentially the hardware of the APCPMS uses a LVDT as a transducer to convert the height across the flats of the permanently distorted metal sphere to a voltage. The voltage in turn is measured by an analog to digital convertor card housed in the microcomputer card cage. The system converts this digital data to a height then to a pressure using the appropriate polynomial equation(s). The data are in turn stored on a disk and printed out.

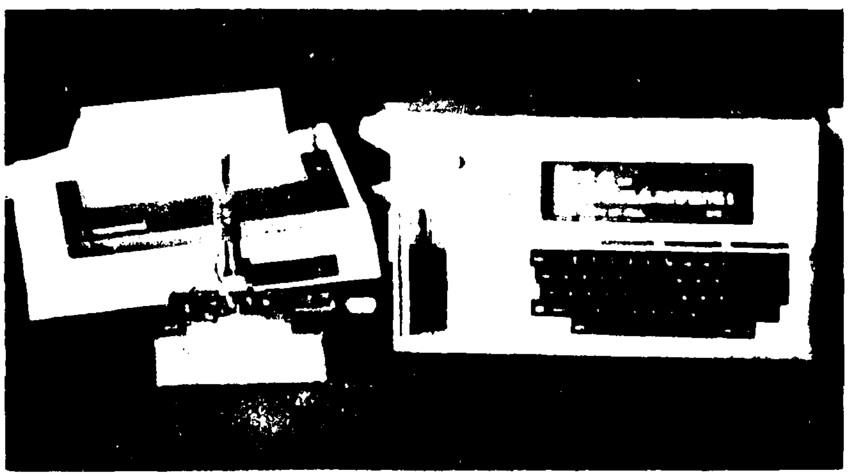


FIGURE 2. Automated Peak Chamber Pressure Measuring System (APCPMS)

The LVDT was acquired for use as a transducer for measurement of copper heights. A gaging fixture with a transport mechanism was designed by System Engineering Support Branch and fabricated at Metalworking Branch, Yuma Proving Ground.

The microcomputer consists of a CPU card, disk drive controller card, bubble memory card, A/D converter card, interface card, and a terminal. See Figures 3 through 7.

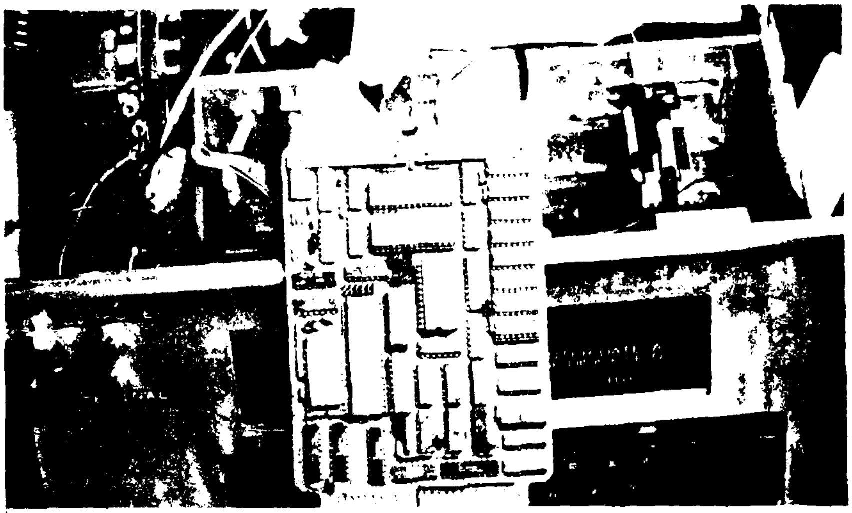


FIGURE 3. Microcomputer CPU Card

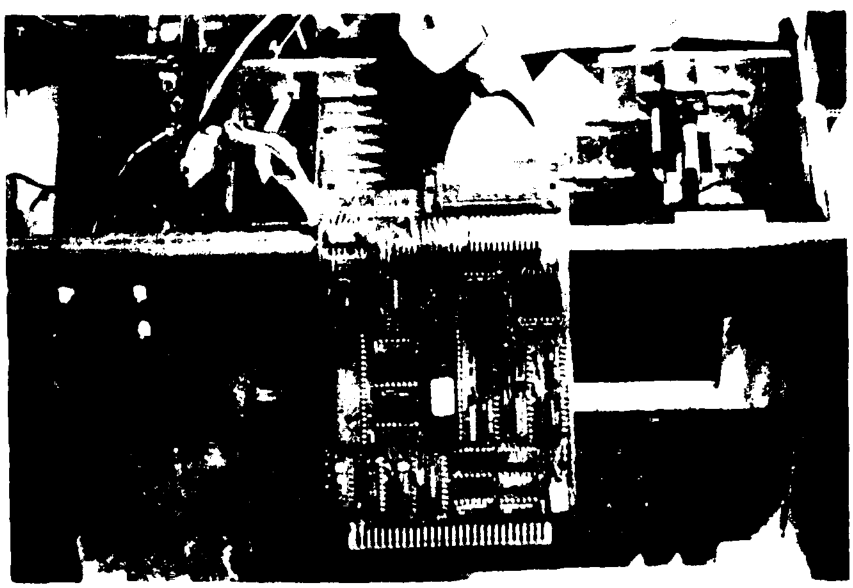


FIGURE 4. Microcomputer disk drive controller card

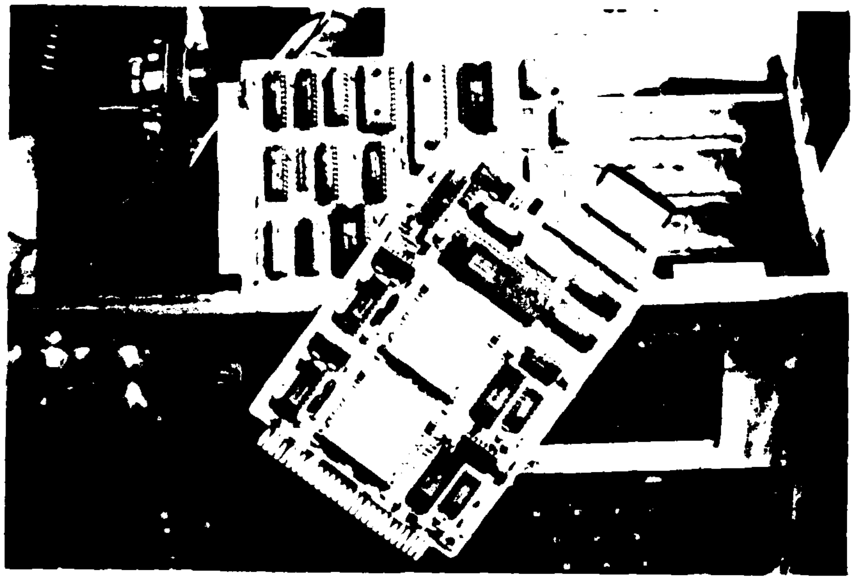


FIGURE 5. Microcomputer bubble memory card

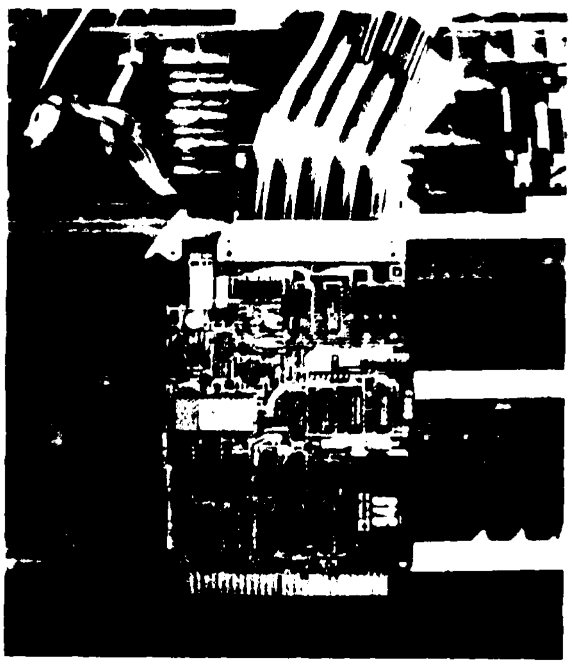


FIGURE 6. Microcomputer A/D converter card

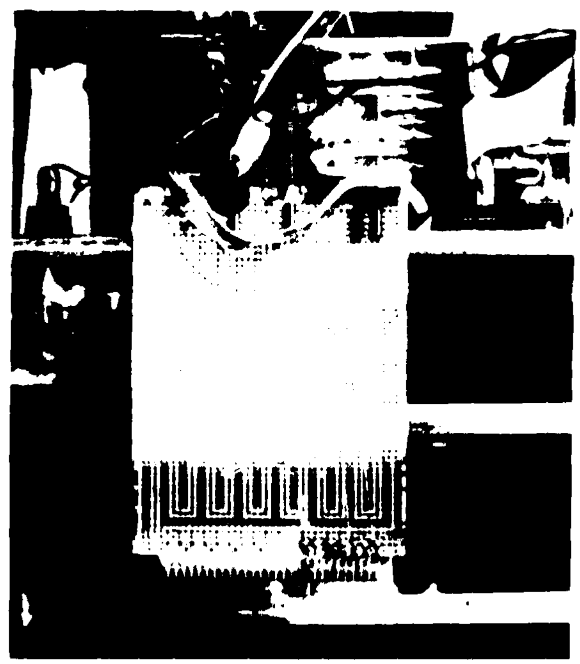


FIGURE 7. Microcomputer interface card

2.3 OPERATIONAL CONCEPT OF APCPMS

Prior to any measurement of the metal spheres, boiler plate information is inputted, then the LVDT is calibrated, and finally the actual test readings and storage of all data occurs. See Operators Overview at Appendix D, Flow Chart at Appendix E, and Computer Program at Appendix F.

2.4 OPERATIONAL PROCEDURE

a. Log into Computer Program (CP). Establish disk file. Follow prompts to input copper lot number and gage type.

b. Enter Boiler Plate Information. Follow prompts to enter project information i.e., TECOM Project No., project title, test firing date(s), P.E. number and name, range request number, gaging operator's name, dates and temperature conditions when copper spheres were measured, metal date, and annealed date.

c. Calibrate the APCPMS. To ensure that the LVDT will accurately measure the height of the permanently distorted metal sphere, which relates directly to peak chamber pressures, it must first be calibrated. This is a self-calibration process done by manually cleaning and drying the LVDT fixture and the (tungsten carbide) calibration spheres in Isopropal alcohol, then completing the following steps.

(1) With the slide below the LVDT in the loading position, manually place one of the three calibration spheres of known heights in the hole of the slide. See Figure 8.

(2) Then manually push the slide with the calibration sphere midway to the left gaging position. See Figure 9.

(3) Once the sphere is in the gaging position, depress the computer enter key and the spring-loaded LVDT* will record relevant data and display a DC voltage which is proportional to the height of the calibration sphere.

(4) Then manually push the slide to the next station, to the extreme left (See Figure 10), where the calibration sphere will eject from the fixture.

(5) This procedure is repeated for each of the three calibration spheres.

If the APCPMS meets calibration criteria, prompts advise how to continue. If calibration is "out of range", prompts advise how to repeat the calibration process or quit the program.

*The LVDT is used as a transducer to convert the height of the calibration sphere to a voltage. The voltage in turn is measured by an analog to digital converter housed in the STD-BUS card cage. Through the use of software, this digital data with the measurement of calibration sphere taken 25 times is converted to an average height.

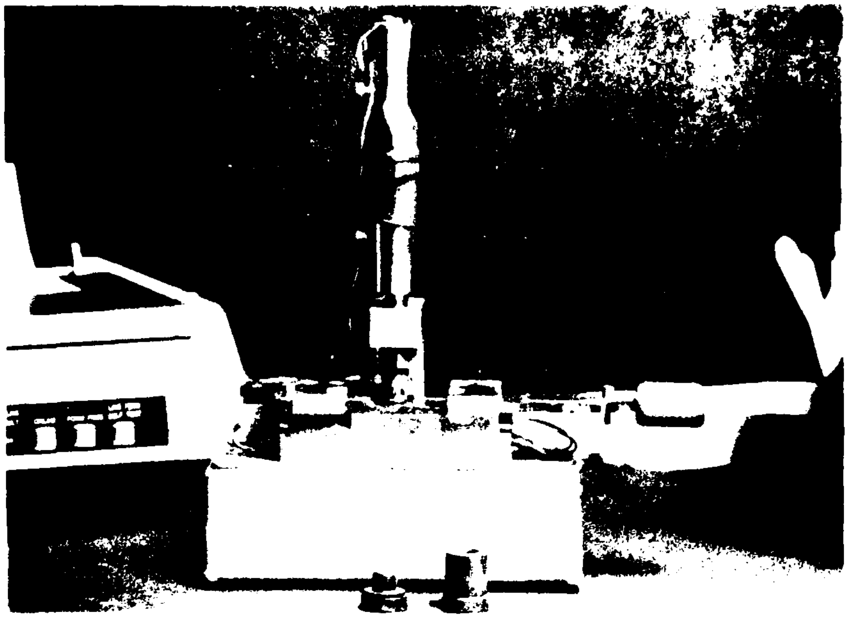


FIGURE 8. The LVDT in loading position

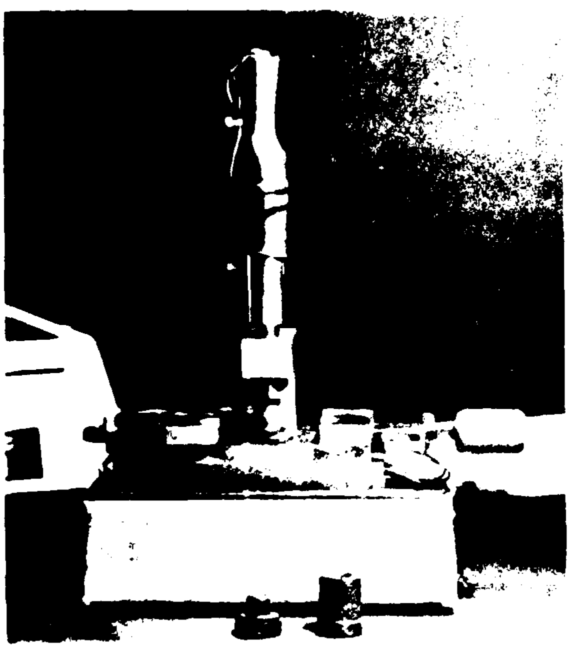


FIGURE 9. The LVDT in the gaging position

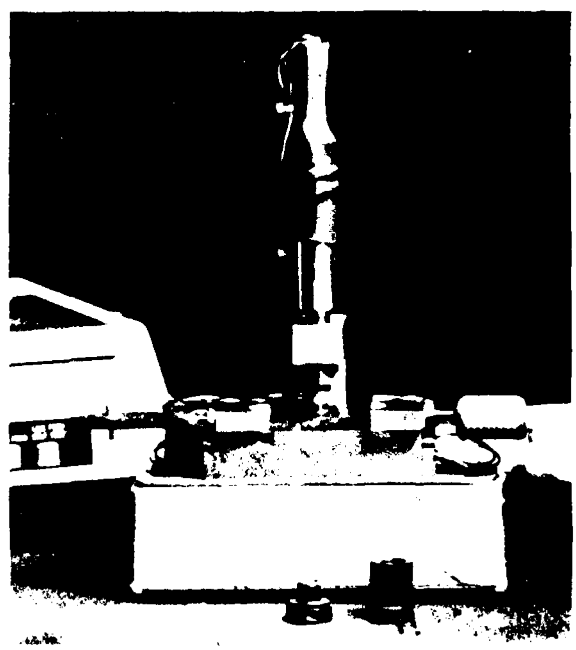


FIGURE 10. The LVDT in the ejection position

Calibration is determined by a linear equation which uses the height outputs from the largest and the smallest calibration sphere. The medium height calibration sphere is compared against the known height of the calibration sphere and if the absolute difference is within 1×10^{-4} inches then the APCPMS has passed calibration test.

d. Obtain Peak Chamber Pressure Measurements. Once the APCPMS is calibrated, average peak chamber pressure measurements may be obtained for permanently distorted metal spheres that have been stabilized at 70°F. This is accomplished by first submitting the metal spheres that have been permanently distorted during a firing test to a manual cleaning process that consists of removing the carbon from the flattened portion of the metal sphere by wiping it on hard white paper. Then proceed as follows:

(1) Enter the following data into the computer at the program prompt: tube round number, number of balls per round, temperature of round, temperature of gage, and gage serial number.

(2) With the gage slide in the loading position (to the extreme right), manually place the metal sphere that has been permanently distorted into the hole in the gage slide with the flats horizontal to the fixture.

(3) Manually push the slide with the distorted metal sphere (midway to the left) to the gaging position.

(4) Once the slide is in the gaging position, depress the computer enter key to access the LVDT to display voltage and record relevant data.

(The spring loaded LVDT as a transducer converts the height across the flats of the permanently distorted metal sphere to a voltage. The voltage in turn is measured by an analog to digital converter card housed in the computer card cage. Through the use of software this digital data is converted to an average height with the measurement of the distorted metal sphere taken 25 times. This data is stored in the computer's memory.)

(5) The operator then manually pushes the slide to the next station (to the extreme left) where the distorted metal sphere is ejected from the fixture. If more than one gage was used per tube round number, clean the next sphere to be measured, return to step 2 and follow computer prompts.

NOTE: **If the gages and spheres were conditioned to an ambient temperature of 70°F prior to firing, a temperature correction factor is not needed and the** pressure will only be a function of the height across the flats of the permanently distorted metal sphere. If the temperature height correction factor is needed, i.e., crusher gage and sphere temperature prior to firing test are conditioned to other than 70°F, a 2nd-degree polynomial equation is used to compute the correction factor and is added to the original permanently distorted metal sphere height. If two or more crusher gages are used in one round, the average height is determined by adding the final heights across the flats of the permanently distorted metal sphere and then dividing them by the

number of crusher gages. The computer calculates average peak chamber pressure by establishing the average height of the permanently distorted metal spheres from the LVDT's voltage readings. It then uses a 5th-degree polynomial equation to calculate the average pressure. The results are displayed on the printer, and stored on a floppy disk.

2.5 TRIAL TEST OF APCPMS

On 13 April 1987, three separate tests were conducted which used the Automated Peak Chamber Pressure Measurement System (APCPMS) to determine the peak chamber pressures of eighteen copper spheres. The copper spheres (3/16-inch diameter, APG 02-78 lots) had previously been fired in the M11 Gage, two crusher gages per tube round, at either -35°F or 110°F. After firing, the permanently distorted metal spheres were measured at both the Measurements and Material Analysis Section and Calibration Laboratory. The Measurements and Material Analysis Section used a 1-inch, hand-held digital micrometer. The spheres were then measured in three separate tests using the APCPMS. Before each run, the gage was recalibrated to ensure data reliability. Table 1 depicts the results of the APCPMS tests in terms of the spheres' height, then compares this data with the Measurements and Material Analysis Section and Calibration Laboratory results.

TABLE 1. Height Measurement Comparison of Distorted Metal Spheres

Gage Ser No.	Temp (°F)	Tube Rnd No.	M and M Analysis Height**	Calibration Laboratory Height	APCPMS Height Test 1	Test 2	Test 3
62175	-35	837	.1499	.1500	.1501	.1501	.1502
44843	-35	837	.1500	.1502	.1504	.1502	.1505
61221	-35	838	.1492	.1495	.1495	.1495	.1496
36110	-35	838	.1480	.1483	.1483	.1482	.1485
44030	-35	839	.1488	.1491	*.1505	.1492	.1492
42723	-35	839	.1495	.1497	.1498	.1497	.1499
43868	-35	840	.1480	.1483	.1483	.1484	.1485
36165	-35	840	.1479	.1481	.1482	.1481	.1483
67234	-35	841	*.1482	.1486	.1485	.1483	.1486
46110	-35	841	.1490	.1493	.1493	.1494	.1494
20451	+110	842	.1461	.1463	.1463	.1463	.1465
585	+110	842	.1454	.1455	.1457	.1457	.1458
68714	+110	843	.1449	.1451	.1453	.1452	.1453
43599	+110	843	*.1443	.1447	.1447	.1444	.1448
64227	+110	844	.1442	.1445	.1446	.1445	.1446
44500	+110	844	*.1440	.1444	.1445	.1444	.1445
67227	+110	845	.1449	.1450	.1450	.1452	.1452
64170	+110	845	.1446	.1448	.1449	.1448	.1450

*The underlined height measurements are $\geq 4 \times 10^{-4}$ inches different than the calibration measurement.

**The Measurements and Material Analysis Section data are constantly lower than the Calibration Laboratory measurements. Also, the plywood board housing the permanently distorted metal spheres left visible wood shavings on the spheres.

Table 2 denotes the average pressure measurements of the spheres as determined by the Measurements and Material Analysis Section and the APCPMS.

TABLE 2. Average Pressure Comparisons (10^3 psi) from Height Measurements TABLE 1

Avg Pressure M and M Anal.	Average Pressure APCPMS Test 1	Test 2	Test 3
35.2	34.7	34.8	34.6
36.7	36.2	36.3	36.1
36.1	34.9	35.6	35.5
37.4	36.9	36.9	36.8
36.7	36.2	36.3	36.1
36.3	35.9	35.9	35.8
37.4	36.9	37.1	36.9
37.9	37.4	37.5	37.4
37.3	37.0	36.9	36.8

NOTE: USAYPG Calibration Laboratory currently uses TB-9-5210-204-50 Change 2 (Calibration Procedure for Micrometers Caliper Type I, Class 1, Style A,B,C and D and Type 1, Class 2, Types A,B, and C) as a guide to calibrate 1-inch micrometers. Page three, Table 2.2, of this bulletin states that the maximum error in inches for a 0 to 1-inch micrometer is .0002 inches. Therefore, if one was to compare the readings of the same object from two different micrometers that had been calibrated using the above Technical Bulletin, the readings could differ as much as .0004 inches and still be within specifications. Relating this to pressure using the tarage tables for the M11 gage, this .0004 inch ranges from 946.8 to 326.4 psi difference and this is not taking into account any gage block tolerance.

All average final pressures are different. This is due to the following:

a. Physical measurements across flats of the distorted metal sphere are not the same.

b. Temperature correction factor used by Measurements and Material Analysis Section is averaged over a range and is not interpolated.

2.6 ANALYSIS OF TRIAL TEST

The trial test demonstrated that the APCPMS provided more accurate data than the present system used by the Measurements and Material Analysis Section (using the Calibration Laboratory Branch results as a standard, ref Table 1).

This test was conducted with a limited sample size over a narrow pressure range window. It is therefore suggested that further comparison testing be conducted using a 1-inch micrometer and the Automated Peak Chamber Pressure Measurement System using a larger sample size over a greater pressure range.

There is an insufficient sample size and pressure distribution to produce a statistical analysis of this data.

Further hardware and software development of the APCPMS should address:

a. Adopting the IBM compatible computer as standard hardware

b. Utilizing stored data to produce an historical record for analyzing the life cycle of gages

c. Providing an easier method for entry corrections.

2.7 DETAILS OF APCPMS COMPONENTS

2.7.1 Linear Variable Differential Transducer (LVDT)

The LVDT is an electromechanical device that produces an electrical output proportional to the displacement of a separate moveable core. It consists of a primary coil and two secondary coils symmetrically spaced on a cylindrical form. A free-moving, rod-shaped magnetic core inside the coil assembly provides a path for the magnetic flux linking the coils.

When the primary coil is energized by an external AC source, voltages are induced in the two secondary coils. These are connected series opposing, so the two voltages are of opposite polarity. Therefore, the net output of the transducer is the difference between these voltages, which is zero when the core is at the center or null position. When the core is moved from the null position, the induced voltage in the coil toward which the core is move increases, while the induced voltage in the opposite coil decreases. This action produces a differential voltage output that varies linearly with changes in core position. The phase of this output voltage changes abruptly by 180° as the core is moved from one side of the null to the other.

The Automated Peak Chamber Pressure Measurement System uses the Schaevitz DC-operated LVDT Model Number GPD-121-125, to obtain voltage measurements for the copper spheres. The DC-LVDT consists of an AC-operated LVDT and a carrier-signal-conditioning module. Use of thick-film hybrid circuitry permits high-density packaging of all necessary electronics, the LVDT, and the core in one housing. The LVDT model was selected for maximum sensitivity over the limited range of deformation of the crusher. For information regarding the installation of the LVDT, as well as displacement and voltage output data, refer to Appendix G.

2.7.2 Power Supply

The APCPMS uses two separate power supplies: one to the LVDT and the other to the microprocessor. The DC outputs are as follows:

LVDT = +15V
Microprocessor = $\pm$12V and +5V

2.7.3 A/D Converter Card

The Analog Devices Model RTI-1260 Analog Input Card (Figure 6) provides data acquisition of analog signals from up to 32 single-ended or 16 differential voltage inputs. User configurable gains of 1 to 1000 allow input ranges from 10 millivolts to 10 volts. It is set for $\pm$5V for the APCPMS. A sample and hold amplifier and 12-bit A/D converter provide throughputs up to 25,000 channels per second.

The RTI-1260 Analog Input Card comes complete with its own DC/DC converter, allowing the boards to operate directly from the microcomputer +5 volt supply. The card had been modified to respond to I/O port addresses. Input-output instructions are used to interface the STD-BUS microcomputer.

2.7.4 CPU Card

The CPU Card (Figure 3) consists of a Z80 microprocessor; two 8251 UART serial communication channels, one which is configured as a DTE device and the other which is configured as a DCE device; and one 8253 programmable timer containing three 16-bit timing elements. Two channels are designed as the baud rate times for the two UARTS, and the third counter output can be connected via jumper to either of the Z80 interrupt lines.

Eight dynamic RAM chips compound the 64K on-board RAM, and a 28 pin socket is provided for the boot EPROM. A jumper is available to select between 2716 or 2732-2764 EPROMS to provide up to 8K bytes of EPROM space.

Two bipolar proms are used for on and off-board address and I/O port decoding; MC1488/1489 level translation chips are used to convert the TTL UART signals to EIA recommended standard 232 voltage levels.

All of the appropriate buffers to the STD-BUS are included in the system, and an 8mhz or 12mhz crystal is divided to provide a 4mhz or 6mhz input to the Z80. This clock is then divided by two once more to provide a 2mhz or 3mhz input to all of the 8253 clock inputs, thus indication that the baud rate counter values are different for the two different CPU speeds.

2.7.5 Bubble Memory Card

Bubble-tec's PSB-1 BUBBL-CONTROL bubble memory card (Figure 5) is an STD-BUS compatible, solid-state mass storage system. The bubble memory operates with the Z80 CPU Card to provide 128K-bytes of non-volatile mass-storage. For information regarding the installation, programming and maintenance of PSB-1 bubble memory card, please refer to Bubble-tec's 1984 Technical Manual for the PSB-1 BUBBL-MACHINE.

2.7.6 Disk Controller

The Disk Controller Printed Circuit Board (Figure 4) is based upon the

Intel 8272. It has a DMA controller and will interface with a 5 1/4-inch and 8-inch disk drive.

2.7.7 Boot EPROM Sequence

The boot EPROM located on the CPU card is mapped in to the low area of memory on power up (0000-1fffhex). Normally this is a 5-volt 2716 type EPROM. Other byte-wide type EPROM/ROMS may be used, such as 2732 and 2764. If a 2716 is not used, JP1 must be changed to pins 3 to 2. The speed of the EPROM must be 350ns for a 6mhz CPU, and 450ns for a 4mhz CPU. A 2716 and 2732 should be shifted, so pin 1 of the IC is in pin 3 of the socket.

When the unit is powered up, the EPROM is mapped in a 0000-1fffhex, but only for the maximum size (8K), the memory of that EPROM will repeat on the boundary of its size. In other words, if a 2716 is used (2K), the code located at 000hex will be known because of the way the EPROM maps itself out of memory. The EPROM will be disabled (no longer in memory) when the last location that can be addressed by the EPROM will contain a jump instruction to the code in RAM that is to be run next. With EPROMS smaller than the maximum size, the address that will be addressed by a read of location 1fffhex is the last physical address of the EPROM. In a 2716, this is 7ffhex, in a 2732, it is a fffhex.

SECTION 3. APPENDICES

APPENDIX A. TEST DIRECTIVE

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005 – 5055

REPLY TO
ATTENTION OF

AMSTE-TC-I

SUBJECT: Test Directive for Three Instrumentation Development Tasks: Miniaturized Low Power Instrumentation, Project 5-CO-YPO-MLP-701; Adv Electro-Optical Data Acc & Processing System, Project 5-CO-YPO-EOS-701; and Automation and Remote Control, Project 5-CO-YPO-ARC-701

Commander
U.S. Army Yuma Proving Ground
ATTN: STEYP-MT-MF
Yuma, Arizona 85365-9102

1. Reference:

a. TECOM Reg 70-24, 22 June 1981, Documenting TECOM Testing, Research, Development and Acquisition.

b. TECOM Reg 70-3, 22 January 1981, Instrumentation Development and Acquisition Plan.

2. Subject efforts are assigned to YPG for accomplishment in accordance with references. The TECOM Project Numbers are assigned as indicated by enclosures 1, 2 and 3.

3. The test project is not anticipated to present any safety or potential health hazards to test personnel. However, YPG should exercise normal caution in conduct of this effort.

4. The environmental aspects of this effort should be reviewed. If review indicates no further evaluation is necessary, a Record of Environmental Consideration (REC) will be prepared.

5. Upon receipt of this directive, test milestone schedules will be reviewed in light of current workload and resources in accordance with TECOM Regulation 70-8. If rescheduling is necessary and the sponsor nonconcurs, a letter citing particulars, together with recommendations will be forwarded to the Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TC-I, no later than 20 days after receipt of this directive. If reschedules are concurred in by the sponsor, direct entry can be made by the test agency.

AMSTE-TC-I 6 OCT 1986

SUBJECT: Test Directive for Three Instrumentation Development Tasks: Miniaturized Low Power Instrumentation, Project 5-CO-YPO-MLP-701; Adv Electro-Optical Data Acc & Processing System, Project 5-CO-YPO-EOS-701; and Automation and Remote Control, Project 5-CO-YPO-ARC-701

6. TECOM - Providing Leaders the Decisive Edge.

FOR THE COMMANDER:

3 Encls

JOHN D. PHELPS
Chief, Instrumentation Division

CF:
Cdr, YPG, ATTN: STEYP-MT-TS

APPENDIX B. TARAGE EQUATIONS

The Physical Test Branch at Aberdeen Proving Grounds (APG) procures copper spheres used throughout the Test and Evaluation Command to determine peak firing chamber pressure of weapon systems. Under laboratory condition they derive the necessary tarage tables and associated polynomial equations for each lot of copper spheres. Specifically, this software uses the following 5th-degree polynomial equation to calculate the pressures with the crusher gage/spheres conditioned at 70°.

The equation for copper lot number APG 2-78 is as follows:

x = (100 times final height) -15

Coefficents:

a = 548.105785
b = -167.281238
c = 6.08384059
d = -0.312518886
e = 0.11374256
f = -0.0082876067

$$\text{Load (lbs)} = a + bx + cx^2 + dx^3 + ex^4 + fx^5$$

Pressure (psi) = (Piston Area)(Load)

For more information regarding the development of this equation reference the 16 March 1979 Analytical Branch Report 79-AB-19, "Calibration of Copper Spheres."

APPENDIX C. TEMPERATURE CORRECTION EQUATIONS

The Physical Test Branch at Aberdeen Proving Grounds derives the tarage tables and appropriates polynomial equation(s) under laboratory conditions with the crusher gage/sphere at 70°F. The temperature of the metal sphere affects its response to an applied force. Some firing programs condition the gage and metal sphere to other than 70°F. To compensate for this temperature difference, APG has derived an empirical relationship between the temperature of the metal sphere in the crusher gage and its permanent deformation using a 2nd-degree polynomial equation.

Equation for copper lot number APG 2-78 is as follows:

x= Final actual height obtained at extreme temperature.

Coefficents:

$g = -0.0000078232$
$h = -0.000819123$
$i = \ \ 0.004874564$

$$\frac{df}{dt} = g + hx + ix^2$$

Δf (Height correction back to 70°F) = $(g + hx + Ix^2)\ (T-70°)(-1)$

The height correction factor is added to the actual measured height of the permanently deformed metal sphere before the pressure is calculated.

For more information regarding the development of this equation reference the 17 October 1979 Analytical Branch Report 79-AB-76, "Calibration of Ball Pressure Gages For Temperature Effects."

APPENDIX D. OPERATOR OVERVIEW FOR APCPMS

After the computer is turned on the following sequence will be displayed on the screen. Provide input where required and press ENTER at end of each input.

1. A> Initial prompt when computer is turned on.

2. A>B: Operator input to go from Drive A to B.

3. B> MBasic CU Operator input loading MBasic then program CU.

4. Letter code MM DD YY XX Operator input data file name on disk.

5. Are you starting new file? (Y/N)
   Operator input if Y then continues to Step 6 if N, then goes to print out routine for existing file on disk.

6. Copper Lot Number APG XXXX
   Operator input Lot Number (presently using 0278 Lot)
   If any other number or letters are used this program will state NO equation for that lot number, do you want to try again (Y/N)? If No then program ends.

7. Gage Type:
   Present gage types used are M-11, T-13, or T-17. If any other numbers or letters are used, this program will state NO equation for that gage type, do you want to try again (Y/N)? If no then program ends.

8. Boilerplate Input:

   a. TECOM Number
   b. Project Title
   c. Test Firing Dates (MM DD YY MM DD YY)
   d. Project Engineer Number and Name
   e. Range Schedule Request Number
   f. Name of Person Gaging Copper
   g. Dates and temperature condition when the copper was measured (MM DD YY MM DD YY FF)
   h. Metal Date YY

9. Calibration (Input independent of size of calibration sphere)

   a. Load + Calibration Gage Number 1 press return when ready
   b. Load + Calibration Gage Number 2 press return when ready
   c. Load + Calibration Gage Number 3 press return when ready

NOTE: If calibration is out of range i.e., medium calibration sphere absolute measurement is $>1\text{x}10^{-4}$ inches different then the calculation

measurement then the operator is ask do you want to try (Y/N)? If NO the program ends. If YES step 9 is repeated. After successful calibration has been achieved, the program°s next question to the operator is:

10. Input tube round number or zero to close file

11. Input number of balls (number of spheres used per tube round number)

12. Input temperature of round FFF (Preconditioned temperature of round)

13. Input temperature of gage FFF (Preconditioned temperature of gage)

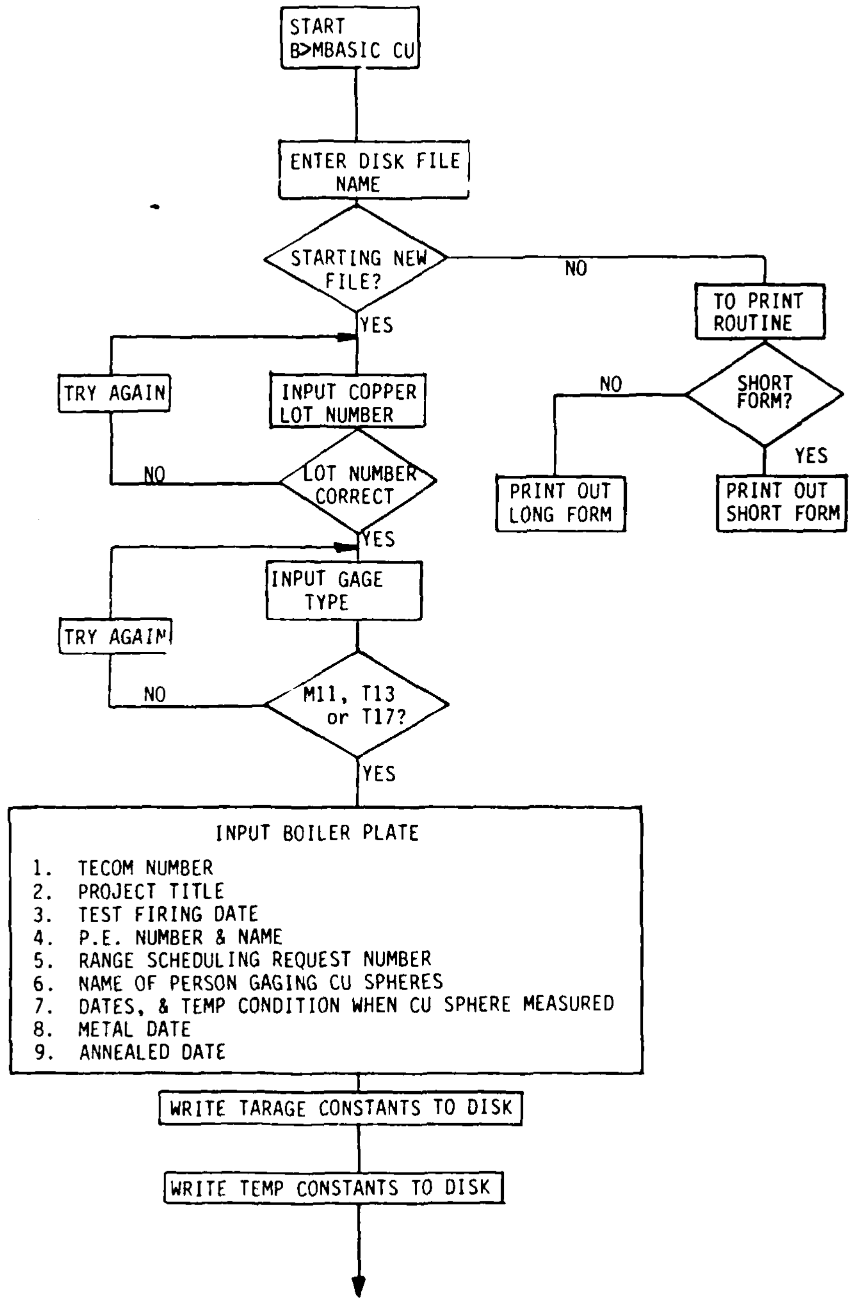
14. Input gage serial number

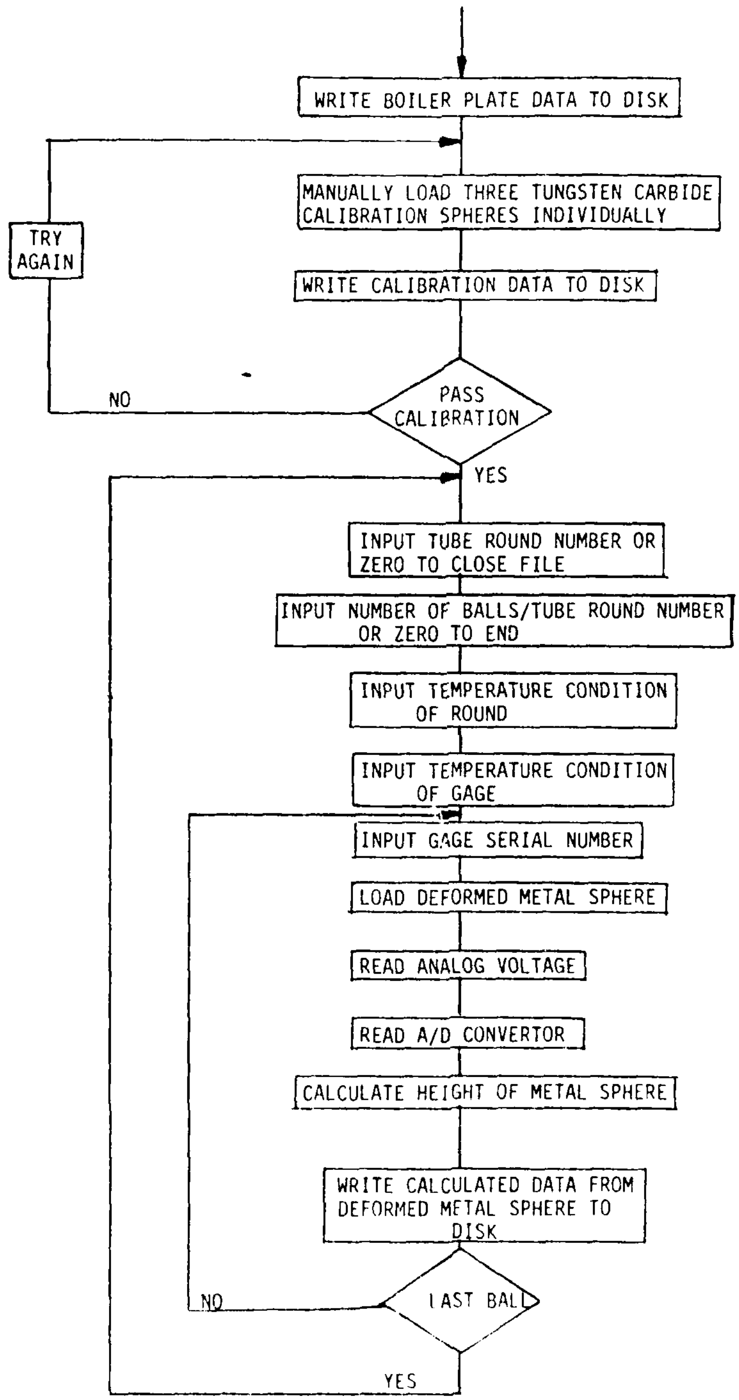
15. Load ball. Press ENTER when ready. The operator loads metal sphere in hole in slide and pushes the slide (midway to the left) to the gaging position. Once the sphere is in the gaging position, the operator will press ENTER to store this data in microcomputer. The operator will push the slide to the next station (to the extreme left) ejecting the sphere from the fixture. Steps 14 & 15 are repeated as many times as called out in step 11. If the pressure difference between set of gages in the same tube round number is equal to or exceeded by 5%, the operator is asked to set aside gages for further evaluation.

16. When this is completed the program will go to Step 10 through Step 16 until there is a zero input in Step 10 to close the file.

LEGEND: MM = Month i.e., 01 = Jan... 12 = Dec
DD = Day i.e., 01...31
YY = Last two digits of year i.e., 1978 = 78
XX = Unique number
FF = Temperature in (°F)
FFF= Temperature in (°F)

APPENDIX E. FLOW CHART FOR ACMS COMPUTER PROGRAM




WRITE BOILER PLATE DATA TO DISK
MANUALLY LOAD THREE TUNGSTEN CARBIDE CALIBRATION SPHERES INDIVIDUALLY
TRY AGAIN
WRITE CALIBRATION DATA TO DISK
NO
PASS CALIBRATION
YES
INPUT TUBE ROUND NUMBER OR ZERO TO CLOSE FILE
INPUT NUMBER OF BALLS/TUBE ROUND NUMBER OR ZERO TO END
INPUT TEMPERATURE CONDITION OF ROUND
INPUT TEMPERATURE CONDITION OF GAGE
INPUT GAGE SERIAL NUMBER
LOAD DEFORMED METAL SPHERE
READ ANALOG VOLTAGE
READ A/D CONVERTOR
CALCULATE HEIGHT OF METAL SPHERE
WRITE CALCULATED DATA FROM DEFORMED METAL SPHERE TO DISK
NO
LAST BALL
YES

APPENDIX F. APCPMS COMPUTER PROGRAM

```
10 REM PROGRAM FOR COPPER CRUSHER GAGE M11 T13 AND T17 USING COPPER LOT NUMBER APG 0278 (US ARMY YUMA PROVING GROUND AV/899-3131 BJ
BUZZO / TE ELLISON 4/6/1987)
20 IOBYTE=PEEK(3) : IOBYTE=IOBYTE AND &H3F : IOBYTE=IOBYTE+&H40 : POKE 3,IOBYTE
30 INPUT "ENTER DATE AND LETTER CODE (MMDDYYXX) OF DISK FILE NAME"; P$ : P$="B:"+P$
40 INPUT "ARE YOU STARTING A NEW FILE (Y/N) ?" ; M$
50 IF M$<>"Y" AND M$<>"y" THEN GOSUB  1660 : GOTO 10
60 DIM PRESS (4)
70 REM ----------------------------------- TARAGE CONSTANTS ------------------------------------------------------------------
80 A#=548.105785#
90 B#=-167.281238#
100 C#=6.083840590000006#
110 D#=-.3125188886#
120 E#=.11374256#
130 F#=-.0082876067#
140 REM ----------------------------------- TEMPERATURE CONSTANTS -------------------------------------------------------------
150 G#=-.0000078232#
160 H#=-8.191230000000176D-04
170 I#=.00487456#
180 REM ----------------------------------- HEADINGS --------------------------------------------------------------------------
190 PRINT "COPPER CRUSHER GAGE PROGRAM"
200 INPUT "COPPER LOT NUMBER APGXXXX";L$
210 IF RIGHT$(L$,4)="0278" THEN 260  '  LOT NUMBER OK
220 INPUT "NO EQUATION FOR THAT COPPER LOT NUMBER DO YOU WANT TO TRY AGAIN (Y/N) " ;M$  ' LOT NUMBER BAD
230 IF M$="Y" OR M$="y" THEN 200  '  RE ENTER LOT NUMBER
240 GOTO 2530  '  TO EXIT
250 REM ----------------------------------------------------------------------
260 INPUT "GAGE TYPE M11 OR T13 OR T17";D$
270 PRINT (D$)
280 R=0
290 IF D$="M11" THEN R=60  '  GAGE TYPE
300 IF D$="T13" THEN R=10  '  GAGE TYPE
310 IF D$="T17" THEN R=15  '  GAGE TYPE
320 IF R<>0 THEN 370
330 INPUT "NO EQUATION FOR THAT GAGE TYPE. DO YOU WANT TO TRY AGAIN (Y/N) ?" ;M$
340 IF M$="Y" OR M$="y" THEN 260  '  RE ENTER GAGE TYPE
350 GOTO 2530  '  TO EXIT
360 REM ----------------------------------------------------------------------
370 INPUT "TECOM NUMBER";A$
380 INPUT "TEST PROJECT TITLE";B$
390 INPUT "TEST FIRING DATE(S) MMDDYYMMDDYY";C$
400 INPUT "PROJECT ENGINEER NUMBER AND NAME";G$
410 INPUT "RANGE SCHEDULE REQUEST NUMBER";H$
420 INPUT "NAME OF PERSON GAGING COPPER SPHERE";PG$
430 INPUT "DATE(S) AND TEMPETURE CONDITION WHEN COPPER WAS MEASURED MMDDYYMMDDYYFF";I$
440 INPUT "COPPER METAL DATE YY";J$
450 INPUT "COPPER ANNEALED DATE YY";K$
460 OPEN "O",1,P$
470 REM (TARAGE CONSTANTS)
480 WRITE  #1  ,A#,B#,C#,D#,E#,F#
490 REM (TEMPERATURE CONSTANTS)
500 WRITE  #1  ,G#,H#,I#
510 REM (CU LOT NUM), (GAGE TYPE), (TECOM NO), (TEST TITLE), (FIRING DATES), (PE NO & NAME),
520 REM (RANGE SCHEDULE NO), (NAME PERSON GAGING CU), (DATE & TEMP WHEN CU MEAURED),
530 REM (METAL), (ANNEALD).
540 WRITE  #1  ,L$,D$,A$,B$,C$,G$,H$,PG$,I$,J$,K$
550 REM ----------------------------------- CALIBRATION -----------------------------------------------------------------------
560 PRINT "INSERT CALIBRATION GAGE NUMBER ONE; PRESS ENTER WHEN READY"
570 IF INKEY$ <> CHR$(13) THEN 570
580 GOSUB 2380  '  MAKES MEASUREMENTS
```

```
590 X1=Z(2)  '  AVERAGE VOLTAGE MEASUREMENTS OF LVDT
600 PRINT "INSERT CALIBRATION GAGE NUMBER TWO; PRESS ENTER WHEN READY"
610 IF INKEY$ <> CHR$(13) THEN 610
620 GOSUB 2380  '  MAKES MEASUREMENTS
630 X2=Z(2)
640 PRINT "INSERT CALIBRATION GAGE NUMBER THREE; PRESS ENTER WHEN READY"
650 IF INKEY$<> CHR$(13) THEN 650
660 GOSUB 2380  '  MAKES MEASUREMENTS
670 X3=Z(2)
680 REM ------ ------------------------------- SORT CALIBRATION BALLS ------------------------------------------------------------
690 IF X1>X2 THEN SWAP X1,X2
700 IF X2>X3 THEN SWAP X2,X3
710 IF X1>X2 THEN SWAP X1,X2
720 LPRINT "X1="X1;"X2="X2;"X3="X3;"VOLTAGE LVDT CALIBRATION BALL"
730 Y3=.18705 : Y2=.13534 : Y1=.11857  '  BALL HEIGHTS
740 LPRINT "Y1="Y1;"Y2="Y2;"Y3="Y3;"CALIBRATION BALL MEASURED HEIGHT"
750 M=(Y3-Y1)/(X3-X1)
760 LPRINT "SLOPE=" M
770 B=M*(-X1)+Y1
780 LPRINT "Y INTERCEPT=" B
790 REM -------------------------------------- LINEAR EQUATION -------------
800 LPRINT"Y=";M"X";
810 IF B>0 THEN LPRINT "+" ELSE LPRINT "-"
820 REM ----------------------------------------------------------------------
830 Y=X2*M+B
840 IF M+B=0 THEN 560
850 DIF=Y2-Y
860 LPRINT "Y2=" Y2;"CALIBRATION BALL MEASURED  HEIGHT"
870 LPRINT "Y="  Y;"CALIBRATION BALL CALCULATED HEIGHT"
880 LPRINT "DIFFERENCE="DIF  '  HEIGHT
890 REM ((3) LVDT VOLTAGES), ((3) MEASURED HEIGHTS), (SLOPE), (INTERCEPT),
900 REM (BALL MEASURED HEIGHT), (CALCULATED HEIGHT), (DIFFERENCE MEASURED-CALCULATED).
910 WRITE  #1  ,X1,X2,X3,Y1,Y2,Y3,M,B,Y2,Y,DIF
920 LPRINT
930  IF ABS (DIF)<.0001 GOTO 990  '  CHECK TO SEE IF THE INSTERMENT IS CALIBRATED
940 LPRINT "CALIBRATION IS OUT OF RANGE. DO YOU WANT TO TRY AGAIN (Y/N)"
950 INPUT "Calibration is out of range. Do you want to try again (Y/N)";M$
960 IF M$="Y" OR M$="y" THEN 560
970 GOTO 2530  '  TO EXIT
980 REM ------------------------------------ ROUND / ROUND DATA ------------------------------------------------------------
990 INPUT "TUBE ROUND NUMBER OR ZERO TO CLOSE FILE AND STOP";NM
1000 IF NM=0 THEN 2340  ' TO CLOSE
1010 LPRINT "TUBE ROUND NUMBER = ";NM
1020 INPUT "NUMBER OF BALLS/ROUND OR ZERO TO STOP";BALLS
1030 IF BALLS=0 THEN 2530  '  END
1040 LPRINT "NUMBER OF BALLS =";BALLS
1050 INPUT "TEMPERATURE CONDITION OF ROUND FFF";FF
1060 INPUT "TEMPERATURE CONDITION OF GAGE FFF ";T
1070 REM (TUBE ROUND NUMBER), (NUMBER OF BALLS/ROUND), (TEMP COND OF ROUND), (TEMP COND OF GAGE)
1080 WRITE  #1  ,NM,BALLS,FF,T
1090 OE=0
1100 HI=0
1110 REM--------------------------- ------- INPUT ONE BALL AT A TIME ---- - --------------------------- -------------------
1120 FOR BZ=1 TO BALLS
1130 INPUT  "INPUT GAGE SERIAL NUMBER";E
1140 LPRINT "GAGE SERIAL # =";E
1150 PRINT "LOAD BALL; PRESS ENTER WHEN READY"
1160 IF INKEY$ <> CHR$(13) THEN 1160
1170 GOSUB 2380  '  MAKES MEASUREMENTS
1180 Y=Z(2)*M+B
```

```
1190 LPRINT "HEIGHT BEFORE TEMP ADJ  Y=";Y;"VOLTS =";Z(2)
1200 X#=(100*Y)-15
1210 LDO=((((F#*X#+E#)*X#+D#)*X#+C#)*X#+B#)*X#+A#
1220 Z=R*LDO
1230 LPRINT "PRESSURE BEFORE TEMP ADJ =";Z
1240 X#=Y
1250 TEMP=(I# * X# +H#) * X# +G#
1260 CO=(TEMP * (T-70)*-1)
1270 LPRINT "TEMPERATURE ADJUSTMENT IN INCHES=";CO
1280 HT=Y+CO
1290 LPRINT "HEIGHT AFTER TEMP ADJ  =";HT;" AT GAGE TEMP ";T
1300 X#=(100 * HT) - 15
1310 LDO = ((((F# * X# + E#)  * X# + D#) * X# + C#) * X# + B#) * X# + A#
1320 PRESSURE=R*LDO
1330 PRESS (BZ)=PRESSURE
1340 LPRINT "PRESSURE AFTER TEMP ADJ =";PRESSURE;"USING ";D$;" GAGE"
1350 PRINT USING "####.# ";PRESSURE/1000;
1360 HI=HI+Y
1370 DE=DE+PRESSURE
1380 REM  (GAGE SERIAL NO), (HEIGHT BEFORE TEMP ADJ),
1390 REM (VOLTS BEFORE TEMP ADJ), (PRESSURE BEFORE TEMP ADJ),
1400 REM  (TEMP ADJ IN INCHES), (HEIGHT AFTER TEMP ADJ), (PRESSURE AFTER TEMP ADJ),
1410 WRITE  #1  ,E,Y,Z(2),Z,CO,HT,PRESSURE
1420 NEXT BZ
1430 AVHI=HI/BALLS
1440 REM ------------------------------------ MAX PRESSURE SORT IN ASCENDING ORDER ------------------------------------------
1450 FOR I = 1 TO BALLS
1460 FOR J= 1 TO BALLS
1470 IF PRESS (I)=>PRESS (J) THEN 1510
1480 TEMP = PRESS (I)
1490 PRESS (I)=PRESS (J)
1500 PRESS (J)=TEMP
1510 NEXT J
1520 NEXT I
1530 REM------------------------------------- MAX PRESSURE DIFFERENCE BETWEEN GAGES -----------------------------------------
1540 K=((PRESS(BALLS)-PRESS(1))/PRESS(BALLS))*100
1550 LPRINT "MAX PERCENT PRESSURE DIFFERENCE BETWEEN GAGES = ";K
1560 IF  K<5 THEN 1590
1570 LPRINT "PRESSURE DIFFERENCE EXCEEDS 5% BETWEEN GAGES. SET ASIDE GAGES FOR FURTHER EVALUATION"
1580 PRINT "PRESSURE DIFFERENCE EXCEEDS 5% BETWEEN GAGES. SET ASIDE GAGES FOR FURTHER EVALUATION"
1590 AV=DE/BALLS
1600 LPRINT "AVERAGE PRESSURE = ";AV; "USING "; BALLS; "GAGE TEMP = ";T
1610 LPRINT "AVERAGE HEIGHT = ";AVHI; "USING "; BALLS; "GAGE TEMP ="; T
1620 REM (MAX % PRESS DIFFERENCE BETWEEN GAGES), (AVERAGE PRESSURE), (AVERAGE HEIGHT).
1630 WRITE  #1  ,K,AV,AVHI
1640 GOTO 990
1650 REM --------------- ------------------- PRINT OUT (LONG FORM)------------------------------------------------------------
1660  INPUT "DO YOU WANT THE SHORT FORM (Y/N) ?";M$
1670 IF M$="Y" OR M$="y" THEN GOSUB 2050
1680 PRINT "THIS BEGINS THE PRINT OUT ROUTINE FOR FILE ";RIGHT$(P$,LEN(P$)-2)
1690 OPEN "I",#1,P$
1700 INPUT  #1  ,A#,B#,C#,D#,E#,F#
1710 INPUT  #1  ,G#,H#,I#
1720 INPUT  #1  ,L$,D$,A$,B$,C$,G$,H$,PG$,I$,J$,K$
1730 INPUT  #1  ,X1,X2,X3,Y1,Y2,Y3,M,B,Y2,Y,DIF
1740 J=0
1750 LPRINT "************************************************************************************************************
****"
1760 LPRINT "CLIMATIC CONVERSION TABLE OF PRESSURE GAGE RECORD FOR DISK FILE NAME",RIGHT$(P$,LEN(P$)-2)
1770 LPRINT "TECOM NUMBER",A$, "TEST PROJECT TITLE",B$
```

```
1780 LPRINT "TEST FIRING DATES",C$, "DATE & TEMPETURE CONDITION WHEN THE COPPER WAS MEASURED",I$
1790 LPRINT "PROJECT ENGINEER NUMBER & NAME",G$, "NAME OF PERSON GAGING COPPER",PG$
1800 LPRINT "COPPER LOT NUMBER APG",L$, "TYPE OF GAGE",D$
1810 LPRINT "****************************************************************************************************
****"
1820 IF EOF(1)=-1 THEN 2020
1830 J=J+1
1840 INPUT  #1  ,NM(J),BALLS(J),FF(J),T(J)
1850 LPRINT "TUBE ROUND NUMBER",NM(J),"NUMBER OF BALLS",BALLS(J),"TEMP ROUND",FF(J),"TEMP GAGE,"T(J)
1860 LPRINT "****************************************************************************************************
*****"
1870 FOR I= 1 TO BALLS(J)
1880 INPUT  #1  ,E(I),Y(I),Z2(I),Z(I),CO(I),HT(I),PRESSURE(I)
1890 LPRINT  "GAGE SERIAL NUMBER",E(I)
1900 LPRINT "HEIGHT BEFORE TEMP ADJ",Y(I)
1910 LPRINT "TEMP ADJ IN INCHES",CO(I)
1920 LPRINT "FINAL HEIGHT",HT(I)
1930 LPRINT "PRESSURE",PRESSURE(I)
1940 LPRINT "-----------------------------------------------------------------------------"
1950 NEXT I
1960 INPUT  #1  ,K,AV,AVHI
1970 LPRINT "AVERAGE HEIGHT",AVHI
1980 LPRINT "AVERAGE PRESSURE",AV
1990 LPRINT "MAX % PRESSURE DIFFERENCE BETWEEN GAGES",K
2000 LPRINT "****************************************************************************************************
****"
2010 GOTO 1820
2020 CLOSE 1
2030 GOTO 2530  ' TO EXIT
2040 RETURN
2050 REM ------------------------------------ PRINT OUT (SHORT FORM)----------------------------------------------------
2060 PRINT "THIS BEGINS THE PRINT OUT ROUTINE FOR FILE ";RIGHT$(P$,LEN(P$)-2)
2070 OPEN "I",#1,P$
2080 INPUT  #1  ,A#,B#,C#,D#,E#,F#
2090 INPUT  #1  ,G#,H#,I#
2100 INPUT  #1  ,L$,D$,A$,B$,C$,G$,H$,PG$,I$,J$,K$
2110 INPUT  #1  ,X1,X2,X3,Y1,Y2,Y3,M,B,Y2,Y,DIF
2120 J=0
2130 LPRINT "****************************************************************************************************
****"
2140 LPRINT "CLIMATIC CONVERSION TABLE OF PRESSURE GAGE RECORD FOR DISK FILE NAME",RIGHT$(P$,LEN(P$)-2)
2150 LPRINT "TECOM NUMBER",A$, "TEST PROJECT TITLE",B$
2160 LPRINT "TEST FIRING DATES",C$, "DATE & TEMPETURE CONDITION WHEN THE COPPER WAS MEASURED",I$
2170 LPRINT "PROJECT ENGINEER NUMBER & NAME",G$, "NAME OF PERSON GAGING COPPER",PG$
2180 LPRINT "COPPER LOT NUMBER APG",L$, "TYPE OF GAGE",D$
2190 LPRINT "****************************************************************************************************
****"
2200 IF EOF(1)=-1 THEN 2340
2210 J=J+1
2220 INPUT  #1  ,NM(J),BALLS(J),FF(J),T(J)
2230 LPRINT "TUBE ROUND NUMBER",NM(J),"NUMBER OF BALLS",BALLS(J),"TEMP ROUND",FF(J),"TEMP GAGE,"T(J)
2240 LPRINT "****************************************************************************************************
*****"
2250 FOR I= 1 TO BALLS(J)
2260 INPUT  #1  ,E(I),Y(I),Z2(I),Z(I),CO(I),HT(I),PRESSURE(I)
2270 LPRINT  "GAGE SERIAL NUMBER",E(I)
2280 NEXT I
2290 INPUT  #1  ,K,AV,AVHI
2300 LPRINT "AVERAGE PRESSURE",AV
2310 LPRINT "MAX % PRESSURE DIFFERENCE BETWEEN GAGES",K
```

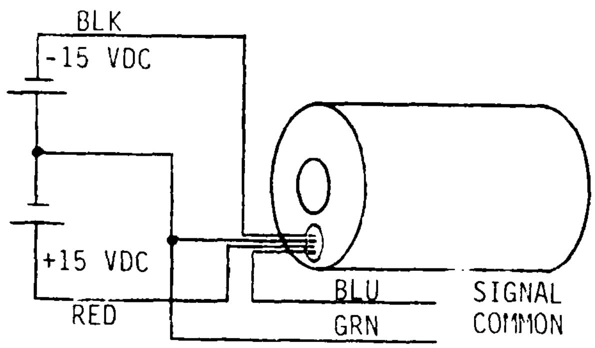
```
2320 LPRINT "****************************************************************************************************
****
2330 GOTO 2200
2340 CLOSE 1
2350 GOTO 2530  'TO EXIT
2360 RETURN
2370 REM ------------------------------------ SUB ROUTINE TO READ LVDT ----------------------------------------------------------
2380 N=25
2390 FOR CH=0 TO 3 : X(CH)=0 : NEXT CH
2400 FOR I=1 TO N
2410 FOR CH=0 TO 3
2420 OUT 155,CH
2430 X(CH)=X(CH)+INP(156)+(256*(INP(157) AND 15))
2440 NEXT CH
2450 NEXT I
2460 FOR CH=0 TO 3
2470 X(CH)=X(CH)-2048*N
2480 Z(CH)=5*X(CH)/N/2048
2490 PRINT USING " ##.###";Z(CH);
2500 NEXT CH
2510 RETURN
2520 REM ---------------------------------------------------------------------------------------------------------------------------
2530 END
```

APPENDIX G. LVDT

1. LVDT Installation

Series DC-D, HCD, and HPD

a. Connect the red and green leads (DC-D model) or pins E and D (HCD or HPD models) to a positive 15-volt DC source. As applicable, make certain that the red lead or pin E is positive. Refer to the illustration for this and the following two steps.



Connector or solder pins
(HCD or HPD)

A..........Output, high
B........Chassis ground
C............(Not used)
D................Common
E.................+15V
F.................-15V

b. Connect the black and green leads (DC-D) or pins F and D (HCD or HPD) to a negative 15-volt DC source. As applicable, make certain that the black lead or pin F is negative.

c. Connect the blue and green leads (DC-D) or pins A and D (HCD or HPD) to a DC readout device. Make certain that the blue lead or pin A, as applicable, is the signal connection.

d. Insert core into LVDT, making certain that the end marked with a red dot is pointed away from the connector or lead end.

e. Apply input power.

f. Move the core of the LVDT to the position where the indicated output voltage reads zero. This is the null point of the LVDT and the point from which positive or negative full scale is measured. When the core is moved toward the lead (or pin) end, an increase in positive voltage is produced. Movement in the other direction causes a negative output. In these series of LVDT's, full displacement of the core will cause an output of 10 volts ± 5 percent.

2. Displacement/Output Data

Displacement (inches)	Output (volts)	Calculated Output (volts)	Deviation
-0.1250	-10.4927	-10.4901	0.0026
-0.1000	- 8.3992	- 8.3933	0.0059
-0.0750	- 6.2997	- 6.2966	0.0031
-0.0500	- 4.1937	- 4.1998	-0.0061
-0.0250	- 2.0961	- 2.1030	-0.0069
0.0250	2.0948	2.0913	-0.0035
0.0500	4.1881	4.1873	-0.0008
0.0750	6.2852	6.2840	-0.0012
0.1000	8.3811	8.3808	-0.0003
0.1250	10.4711	10.4784	0.0073

Scale Factor 83.9V/IN

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